

USER EXPERIENCE DESIGN FOR ELECTRIC MOPEDS

A Thesis
Presented to
The Academic Faculty

by

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In Partial Fulfillment
of the Requirements for the Degree
Master of Industrial Design in the
School of Industrial Design

Georgia Institute of Technology
May 2020

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Date Approved: April 23, 2020

ACKNOWLEDGEMENTS

First and foremost, I would like to especially thank my thesis advisor Dr. Roger Ball of the School of Industrial Design at Georgia Institute of Technology who consistently devoted his time in supporting and guiding me throughout my thesis year. From selecting topics to the final stage of composing this paper, he always encouraged me to take responsibility for my own work and help me to move in the right direction when I run into problems.

I would also like to acknowledge the rest of my thesis committee: Dr. Wei Wang and Prof. Tim Purdy who have participated actively in the design and evaluation stage of this study. Many useful suggestions and resources have been given by them, which later became essential components in the design and development of this study.

I am extremely grateful for all the participants in this study for their time and effort devoted as well as their contributing comments. I would also like to express special thanks to other ID faculties that offered me help during the whole process: Dr. Young-Mi Choi, Tripp Edwards, Amy Fortson, Troy Whyte and Sudie Pennebaker.

Finally, to my caring and loving family members: my deepest gratitude. Your encouraging messages support me to continue my study abroad and support me all the way to this satisfactory ending of my 2-year master program.

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LIST OF SYMBOLS AND ABBREVIATIONS

UI	User Interface
UX	User Experience
SUS	System Usability Scale
HMI	Human-Machine Interaction

SUMMARY

Electric moped sharing, a recent variation of vehicle sharing concepts, are emerging in urban areas to enable commuters short-term access to mopeds on an as-needed basis. User experience problems arise along with the generalization of this trend. A large portion of novice riders are granted access and the shared nature prevents users from taking their time to get familiar with the controls and functions of electric mopeds. The purpose of this study is to gain a deeper understanding of user experience and leveraging design to address the problems. Unlike car and bike sharing, user experience related to electric moped are yet to be explored by literature. To fill this gap, a social media survey and 4 individual workshops were organized to clarify issues interacting with mopeds caused by inexperience and lack of time. A final prototype was designed using an incremental and exploratory approach, which is characterized by the intuitive layout of handlebar controls and smartphone integration. In evaluating the usability and user experience, 9 participants were recruited to do simulation riding using the designed prototype and a standard moped, which serves as the benchmark. The result suggested a higher usability scale for the prototype supplemented by positive comments made on the smartphone integration tactic and system learnability. Possibility of further improvement and methodology design are also discussed in this paper.

CHAPTER 1. INTRODUCTION

1.1 Background

Electric moped sharing, a recent variation of vehicle sharing concepts, is emerging in urban areas to enable commuters short-term access to mopeds on an as-needed basis. Mopeds, being discussed in this study, are defined as “motor driven cycle, a motorcycle with a motor that produces 5-brake horsepower or less.” according to the National Highway Traffic Safety Administration(NHTSA). With this power, a moped can travel up to the speed of 30-35 MPH and have access to most city roads. To distinguish from kick scooters, the vehicle model used by service providers like Bird and Lime, mopeds come with a seat or saddle and should be used in a seated posture.

The recent decade has seen a steady growth in moped sales and ownership [1][2]. As mopeds are playing an increasingly important role in today’s urban transportation, the true benefits it bring to modern commutes are widely discussed and acknowledged: economy, time-efficiency, maneuverability, easy-parking, enjoyment and environmental friendly are motivations that facilitate moped ownership concluded from large-scale surveys [3] and qualitative researches [4]. Along with this popularity, the idea of vehicle share-use is making electric moped even more convenient and accessible to the public by ‘gaining the benefits of a private vehicle (moped) without the costs and burdens of its ownership’ [5]. Originated in San Francisco since 2012, the electric moped sharing services began to meet its success across European countries and then flourishing in Asia and the U.S. By the end of 2018, 85 moped sharing schemes are active in 62 cities globally [6].

1.2 Exploratory literature about electric moped sharing

In line with the process of accumulating shared riders and traceable data, electric moped sharing has started to gain interest in the academic communities. Existing literature contributes to the valuable understanding of service adoption and usage pattern: In a customer segment study that analyzes 2 German e-moped sharing providers[7], age, trip related attributes are deemed to be decisive variables that well-describe service use case : Over 72% of the users aged between 18 and 36, meanwhile, most trip lengths fall in the range from 1-6 km(about 0.5-4 miles). Some clusters can be observed in the existing user segment: lead users (5%), people who repeatedly use the service on weekdays, generating 40% of total revenue. Leisure users (80%) mainly use the service irregularly during the weekends comprising other 40% revenue. Furthermore, the age distribution is confirmed in a second study conducted in Spain[3]. In this paper, the authors further suggested that university students and the higher educated population are power users of moped sharing as they are more sensitive and have higher acceptance for new transportation mode. Conversely, people with higher income are less likely to become frequent users.

Compared to the extensively discussed car-sharing and bike-sharing, electric moped sharing has received much less attention. The above mentioned research findings are mainly generated from qualitative methods like survey, processing and clustering data. As such, there is thereby a need to explore moped sharing from qualitative and subject perspective by focusing on user experience. Additionally, to truly benefit service users and providers, and to promote the future adoption of moped sharing, research findings need to be transferred into implementable solutions.

1.3 Related works

Despite the gap in understanding moped sharing user experience, usability issues that generate in the context of vehicle sharing (i.e. car-sharing) have already been discussed by prior studies. Some user experience problems are common across different vehicle modes, thus count as valid and valuable references. Apart from that, solutions proposed in these papers, the design and evaluation of concepts in the context of the automotive industry are other critical parts of the literature review in supporting the design phase in this study.

1.3.1 User experience of shared vehicles

Most discussed user experience problems are centered around the understanding and access of shared vehicle functionalities. For secondary functions, unfamiliarity may prevent users from accessing it or waste their time. However, for tasks related to a primary driving task or interaction that happens in motion, being unable to react in a timely manner will lead to severe safety hazards.

One primary reason why people choose shared mobility options is due to its convenience and time-efficiency. A usability study of car-sharing [8] pointed out a specific problem of drivers operating a shared vehicle as opposed to their private cars by saying that “users do not take enough time to learn the controls and functions of a car that they are unfamiliar with”. Sometimes, users will even encounter a conflict in cognition because the location of function controls in the shared car is different from their private vehicle, therefore resulting in longer task completion time using the shared model. The proposed solution in this paper was a shared-friendly layout of secondary controls, by synthesizing common placement of popular models in the market. Another study[9] also addresses the

topic of learnability of shared car functions. To make functions better understood by drivers, the researchers suggest a possible solution which is called dashboard layout personalization. This tactic is intended to make the dashboard look more familiar to the user by giving the user freedom to adjust the layout of functions on the dashboard.

1.3.2 Guidelines for vehicle-driver interaction design

Literature that discussed key UX components in the design of vehicle-driver interaction are reviewed to draw up guidelines for the design phase. To start with, the vehicle manufacturing industry is dealing with a challenge of increasing in-vehicle functionalities [10]. This is enabled by developed car infrastructure and sensing capacity and driving by user need. However, this trend is always in dispute as it may distract drivers from the primary driving tasks [11]. Many efforts have been made by designers and researchers to improve the acceptance for secondary in-vehicle functionalities with safety being the premise.

To accommodate multiple features, an increased number and type of interfaces are introduced. As vehicle interfaces are becoming more complex, researchers have investigated the effect of control quantity, placement, type of switch on driving performance and mental workload [12]. Meanwhile, screen display has become widely applied in vehicle interaction design and how it should be integrated into the traditional physical interface has been discussed. An ergonomic investigation conducted by Hyundai motor [13] studied the relationship between control types and display menu design and indicated a good synergy in performance by using liner-type controls (i.e. joystick, mouse stick) together with linear menu layout.

To sum up, function, control and display type placement are key UX components that need to be given special consideration when designing vehicle-driver interaction. More importantly, these components should be well integrated to deliver a consistent user experience.

1.4 Research questions

In this exploratory study, user experience issues underlie in the context of electric moped sharing are investigated. It is crucial to understand how the sharing context will affect user experience(UX) in relation to user segment and vehicle-to-rider interaction. According to previous study on car-sharing, it is hypothesized that electric moped sharing will attract a large portion of novice riders and thus having problems interacting with the unfamiliar share mopeds. The first research question is: “What are the user experience problems novice users would encounter while interacting the shared moped?” TO answer this question, a preliminary probe into the service was conducted to fill the gap of understanding UX problems for electric moped sharing and test this hypothesis, which will be presented in chapter 2.

To address the problem identified from the research phase, the second research question is formulated as follow: “How do we redesign interactions with shared mopeds that support novice riders in overcoming inexperience and unfamiliarity with the vehicle?” A moped interface was proposed in chapter3 to answer the second question. An incremental design process was adopted, where the learnings gathering from 3 rounds of user participated iteration, followed by usability evaluation. Methodology to evaluate the prototype and results will be presented and discussed later in this paper.

CHAPTER 2. PRELIMINARY RESEARCH IN USER EXPERIENCE

The user experience of electric moped sharing service is of particular interest in this present study. Unlike car-sharing and bike-sharing, which have been more scientifically explored in terms of user segment, usability and user experience, electric moped sharing, as a novel mobility mode, is yet to be analyzed. Prior studies about electric moped sharing were conducted mainly in Spain and Germany where mopeds have always been very popular means of transportation even before the service emerged, whereas, in the United States, a country that is car-dominant, the user characteristic could be different. Therefore, in this section, quantitative and qualitative methods will be applied to transfer the existing understanding of user segments into the American context as well as identifying underlying user experience problems that then can be addressed in the following design phase.

2.1 Methods

2.1.1 Survey

With loose licensing requirements, the electric moped sharing service makes mopeds accessible to a huge number of American commuters, among which the majority has little or very few experience with motorcycles. As required by state laws, to be eligible to ride a moped, a motorcycle license is not required if possessing a driver's license. To meet the requirement for limited Institutional Review Board (IRB) review, vulnerable population age below 18 years old are excluded from the study. Active moped ride sharing schemes in the U.S, are making the proposal that recommending an age limit of 21 years

old to be fully responsible for their road safety. Thus, this study adopted this recommendation and screening for participants over 21 years old. Apart from that, the survey also intended to include people that are currently choosing different mobility options as their primary transport mode, such as private vehicles, public transportation, rideshare, etc., to better represent the U.S. commuter population. The survey is mainly distributed through social media platforms. Groups and topics that are related to commuting and transportation are selected to do screening and better deliver the survey to people that are keen on future transportation. In hoping to get as many responded as possible, the survey is designed to be simple and straightforward and is limited to 5 questions. The first 3 are socio demographic questions. Daily commute distance, experience with motorcycles (or any powered-two-wheels), and primary mobility mode are selected to be the matrix that defines user characteristics. Followed by a brief introduction of the electric moped sharing service, to avoid bias and misunderstanding caused by insufficient knowledge. The participants then need to express their opinion and acceptance for the service, which is phrased by ‘Will you use this service or not?’. Based on their answers, they will then select the reasons that best describe their motivation and concerns from the provided assets. For motivations, some examples from the assets are try for fun, connect with public traffic, easy parking, etc. For concerns, the survey provided like, satisfied with current mobility pattern, not safe, can ride under bad weather, etc.

2.1.2 Workshop

In compensating for the quantitative data acquired from the survey, 4 workshops were organized with individual participants to gain more insights on their prospective judgement of the electric moped sharing service, both positively and negatively.

The design challenge of the workshop is trying to acquire ‘realistic’ acceptance data from people that have no prior experience with the service. In tackling this challenge, a lot of assets are provided at the workshop that will-describe and deconstruct the electric moped sharing service. As such, the underlying user experience problems can be uncovered and narrowed down.

Assets provided at the workshop including: 1) a 3 min service intro video from Revel, which is a company currently running the electric moped sharing service in New York. In the video, key components, procedure to use and precaution tips to ride safely are mentioned; 2) a collection of service touchpoint cards: all service touchpoints were documented either by photograph or screenshot and then were printed out as cards with text labels to avoid misunderstanding. The size of each card is limited to 1’’ by 2’’. Touchpoints cover physical, digital and interpersonal interactions. All cards were initially laid out in chronological order when presented to the participants. 3) a collection of 15 factors that will affect the adoption of moped sharing summarized from prior studies [4][14]. These factors describe both motivation and concerns for using the service. 4) a territory mapping that shows the key component of the service.

Move on to the procedure, first off, the participants will be asked some demographic questions to make sure that they match the potential user characteristic and this also helps them do a quick reflection on their mobility experience, which can make the following steps more productive. Following that, the participants will watch the 3-min service intro video provided to establish a first impression and holistic understanding about the service. Then, using the touchpoint cards provided, the participants will create their own journey map. All the touchpoints are laid out on a horizontal axis in a timely order and users will

adjust the vertical position, which is the position on the y-axis, to show their positive/negative attitude for each touchpoint. The y-axis has 5 positions that represent bad, below average, neutral, good and excellent. Taking a deeper look at each touchpoint, participants are asked to imagine and reflect on whether this touchpoint is necessary and how it affects the overall user experience. For instance, this touchpoint makes it easier for me to do something, or I think I will have problems with touchpoint so I can't move on. Along with the process, the participants will explain their rationale using the think aloud tactic. Other materials are provided to support the touchpoint evaluation.

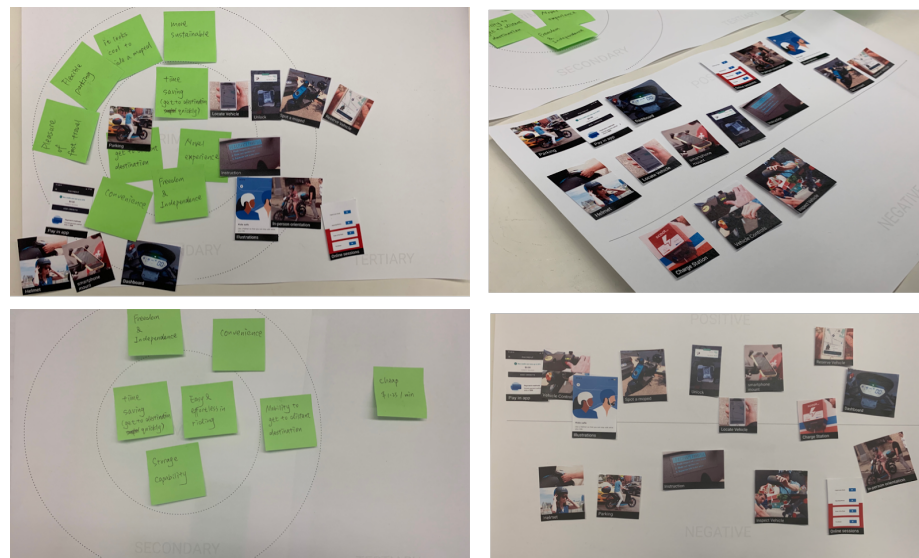


Figure 1 – Example of journey maps created by participants

The participants are recruited via word of mouth and social media groups of design student community. As the method included in this workshop, for instance the user journey map and value proposition, needs effort to learn and comprehend.

2.2 Results

2.2.1 Survey

A total of 73 people filled out the survey and 66 among them are valid responses.

Error! Reference source not found. summarized the sample characteristics in terms of daily commute distance, experience with motorcycles and people's primary mobility choices. The sample shows a higher presence of novice riders (51.52%), followed by experienced riders (33.33%) and intermittent riders (15.15%). 31.826% of the respondents' daily commute distance is under 2miles and 33.33% falls between the distance of 2-5 miles, which combined can be considered as potential users for using moped sharing service for daily commute. As for mobility choices, the distributed sample here complies with the U.S. traffic pattern with 59.09% of the respondents using private vehicles every day; 22.73% of the respondents take public transport frequently; 15.15% of the responses are power users of the share mobility services, like rideshare, bike sharing, etc.

Table 1 – Sample characteristic.

Variables	Subgroup	Respondents Percentage (%)	
Daily commute distance	Under 2 miles	21	31.82
	2-5 miles	22	33.33
	5-10 miles	15	22.74
	over 10 miles	8	12.12
Primary mobility mode	Private vehicle	39	59.09
	Public transportation	15	22.73
	Shared mobility	10	15.15
	Others	2	3.03
Experience with motorcycle	Experienced rider	22	33.33

Intermittent rider	10	15.15
Novice rider	34	51.52

In regards to people's perception and attitude towards using the service: 52% of the responses show interest and said they would use the service if they have access to it. Among them, the majority (41% novice rider, 18% intermittent rider) have zero or a few experience with powered-two-wheels. The other 48% of responses that express negative attitude towards moped sharing has also expressed their concerns. The top 3 reasons for not using this new service are satisfied with current mobility patterns, not safe, not capable of using moped without proper training. This proves that there obviously is an entry barrier for inexperienced and novice riders in terms of safety concerns.

2.2.2 *Workshop*

4 design students were recruited to be the participants of 4 individual workshops. Each lasts about 40min. All four participants have a driver's license and have at least a year of driving experience, which shows that they have basic understanding of road safety. All of them have expressed interest in trying the service in the recruiting process thus can be considered as potential users. Before the workshop begins, some socio demographic data in terms of commuting and mobility pattern are recorded. 3 of them have a daily commute distance less than 5 miles and are considering using shared moped as a back-up option for daily commuting. The other one who lives over 10 miles from campus mainly picturing the use cases as leisure trips, like shopping or sightseeing.

Using the provided touchpoint cards, each participant creates a separate service journey map. Horizontal placement of cards represents participants' subjective attitude

toward different touchpoints. From negative to positive, there are 5 likert scales, then coded as -2 to +2. 4 individual journey maps are synthesized (see figure x) by calculating the mean for attitude scores. The touchpoints are then divided into 3 categories based on the score: beneficial($y > 1$), acceptable ($-1 \leq y \leq 1$), need to improve($y < -1$).

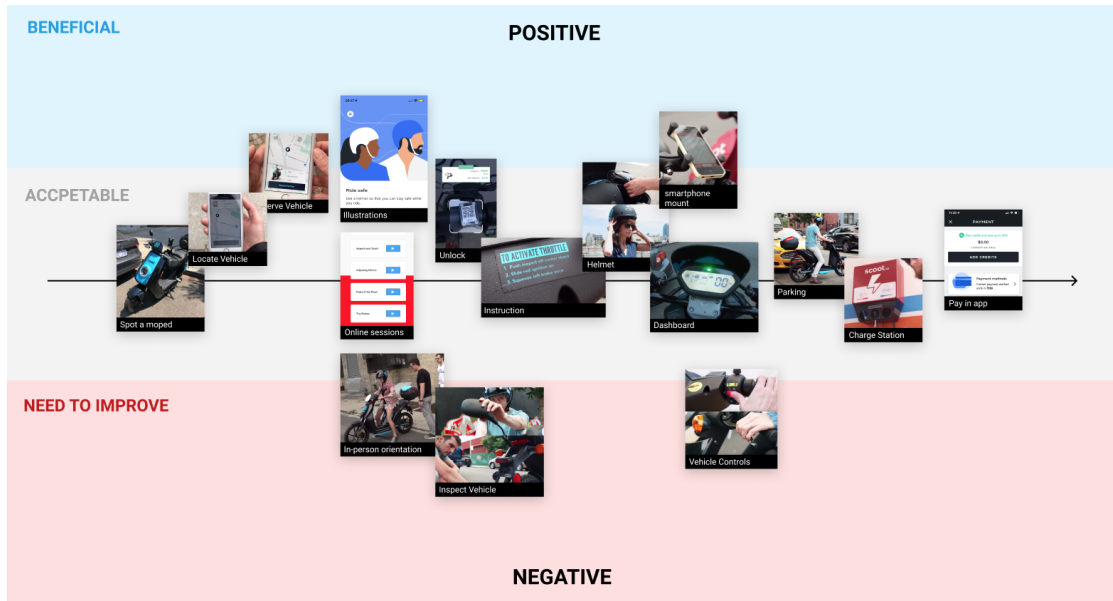


Figure 2 – Synthesized service journey map

The design scope can be narrowed down according to this synthesized service journey map that describes participants' subjective preference and expectation. Using the rideshare moped for the first time is no easy task. Starting with things that need to be improved: 1) In-person orientation: as for now, 3 different means(in-person, video, illustration) are provided to help first-time users develop a basic understanding of the vehicle and how to use it. Among them, the in-person orientation received the worst rating as people are expecting something simple and convenient. 2) Inspect vehicle: This is considered to be impossible to complete without basic knowledge about mopeds. Besides, it is expected that service companies take responsibility for vehicle maintenance and

inspection. Encountering a damaged vehicle will have an extremely negative effect on users' trust for the service. 3) Vehicle controls: In the context of rideshare, the participants are not paying enough attention to secondary controls, once they figure out how to accelerate and brake. Adversely, there are some touchpoints that are perceived positively by participants, including the phone app and smartphone mount, which makes unlocking moped quick and simple also provides a proper place for their phone during the trip.

Apart from that, participants have expressed their concern around their capability of using the vehicle without prior experience. In a car-dependent country like the United States, moped or other powered-two-wheels are generally not very familiar among the population. For novice riders, unfamiliarity associated with the vehicle and the riding context could lead to some practical problem and heavy mental demand. And a lot of the participants' opinions are related to this issue.

The symbol for the ignition/power is confusing.

The controls are easy to understand with instructions. But, even though my brain knows how it is, my body is not able to perform it.

There's a lot going on at the same time.. the app and the controls.

I can't get on the road... I would probably try on sidewalks.. I know it's not safe.

To sum up key findings in this section: 1) novice riders are a large portion of the target user group, which need more help and support, 2) inexperience and unfamiliar with mopeds is inhibiting riders from performing basic tasks like inspect vehicle status and operating secondary controls during the trip.

CHAPTER 3. FROM CONCEPT TO PROTOTYPE

As key user experience issues are summarized from the previous chapter, the scope can be further narrowed down to moped to rider interaction design. In this chapter, a design solution was proposed to tackle the problem of inexperienced and unfamiliarity with moped controls and functionalities. The design solution is characterized by user-generated layout of handlebar controls and an integrated smartphone dashboard. Using the incremental and agile design process, the initial concepts went through 3 rounds of quick iteration with constant user participation. The final output was a high fidelity prototype with all the proposed features working, which was used in the following chapter for usability evaluation.

3.1 Define moped interface

Start with defining the moped interface. Vehicle interface or the human-machine interface(HMI) is a very inclusive concept, which could describe a certain area or space on the vehicle that a user can interact with to control a certain function. Interfaces can be classified by interaction types: physical controls (i.e. buttons, switch, knob), digital screen or display(i.e. touchscreen, lighting,) and other types of interfaces using modality mode like audio, thermal and hand gestures[15]. Apart from interaction type, the location of the interface is another critical part of the design. Taking cars as an example, the most common location of interface including the center stack and steering wheel. Other locations like head-up displays using the space of the windshield are also being developed. The choice of location and interaction type are closely correlated with the designated function and have fundamental impact on the system usability.

Using interaction type, location and function as the matrix, a typical moped interface can be defined as: 1) left and right handlebar controls: a stack of physical controls located around 2 handle grips, mainly within the reach of fingers without removing the hand from the grip. Key functions including throttle, brake, turn signals, horn, lights, etc. 2) center dashboard: mainly used for displaying useful information (like current speed, odometer, status indicator, etc.), some mopeds incorporate interaction features that enable users to adjust the displayed information.

3.2 Design specification

The ultimate goal is to support inexperienced riders by designing easy to understand and easy to learn features. This goal can then be translated to more specific design requirements that can be used to guide the design process and become the evaluation criteria in testing.

Table 2 – Design specification for redesigned moped interface.

Interface	Design specification
Overall	System perceive safe to use during trips; System considered to be easy to learn by novice riders; System consider to be beneficial; User can maintain attention on the road most of the time not getting distracted by interacting with the controls of dashboard;

Handlebar controls	<p>Able to interact with all the physical controls without removing hand from handle grip;</p> <p>Reach out or interact with the controls will not cause uncomfortable feelings (fatigue, stiff, etc.) or excessive effort within an average 10min trip;</p> <p>Able to understand functions associated with physical controls with the provided instruction (text label, symbols);</p> <p>Able to remember the location/layout of controls after 2-3 reps, can operate without looking down;</p>
Dashboard	<p>Able to navigate between all incorporated functions after free exploration;</p> <p>User satisfied with information clarity and can read with quick glance;</p> <p>User satisfied with visual style;</p>

3.3 Design

3.3.1 *In-depth market review*

Before starting the design, an in-depth market review was conducted to 1) understand common layout and location of moped controls, 2) compare and figure out differences between private and shared moped interfaces. 7 moped models were selected (4 popular models in market, 3 being used by shared moped services).

The findings can be summarized as following: 1) The location and interaction type of primary controls (throttle and brake) are very standard while there is opportunity to redesign the layout of secondary controls (turn signal and horn, controls that a rider needs to operate in motion). 2) Compared to private moped models, which have a built-in digital dashboard, shared models only come with a simple dashboard with phone mount to allow users who want to add smartphone functionality during their ride.

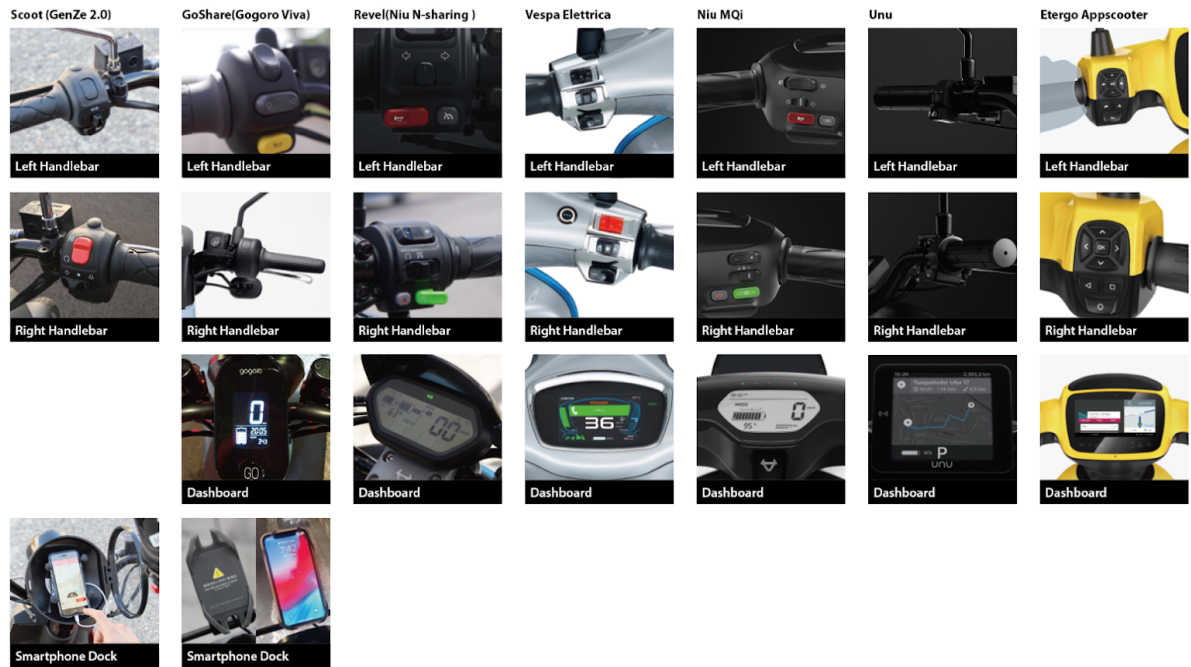


Figure 3 – In-depth market review of moped interfaces

3.3.2 Initial concept

After the in-depth market review, the design scope of handlebar controls are limited to secondary controls that users need to interact with frequently during the trip. As for the dashboard, using a user's private smartphone is choosing to serve as the role of a dashboard meanwhile it can provide additional features with its embedded computing capacity and connectivity. Leveraging smartphones is also desired by users referring to the result of previous workshops where the provided smartphone mount are considered to be beneficial to the overall user experience. Standing from the service provider's perspective, using

smartphones is a cost-effective option as the service comes with a smartphone application and no extra investment need to make in the development of build-in dashboard.

However, as using screens and touchscreen interaction has always been controversial in vehicle design, additional design effort needs to be made in order to mitigate the downside of touchscreen interaction and visual distraction. To this end, a smartphone integrated tactic was proposed, which can be explained by a remote control concept that enables riders using physical buttons located on the handlebar to interact with smartphone dashboard instead of direct interaction, which are expected to increasing the perceived safety of using the moped by novice user as ISO 4151 (ISO 4151:1987) requires that “all hand controls shall be operable without the need of removing the hands from handlebar grips.” Some initial concepts were quickly sketched to explore the possibility of integration between the physical and digital components.

3.3.3 Iteration 1: Define key features

3.3.3.1 Handlebar controls

3 key features for handlebar controls are: turn signal, horn and remote control for smartphone dashboard. In making the moped interface to be share-friendly, it is required that the interaction type and location of these 3 controls be intuitive and doesn't conflict with people's prior cognition.

The first round of the iteration focused on the layout of controls in a limited space around the left handlebar of a moped. 3 Polyhedron bases were designed to add more space and tactility of the handlebar. 5 design student were invited to try different layout and

combination using the provided bases and controls and figure out what feels most intuitive to them. Varied hand sizes were given consideration when selecting participants.

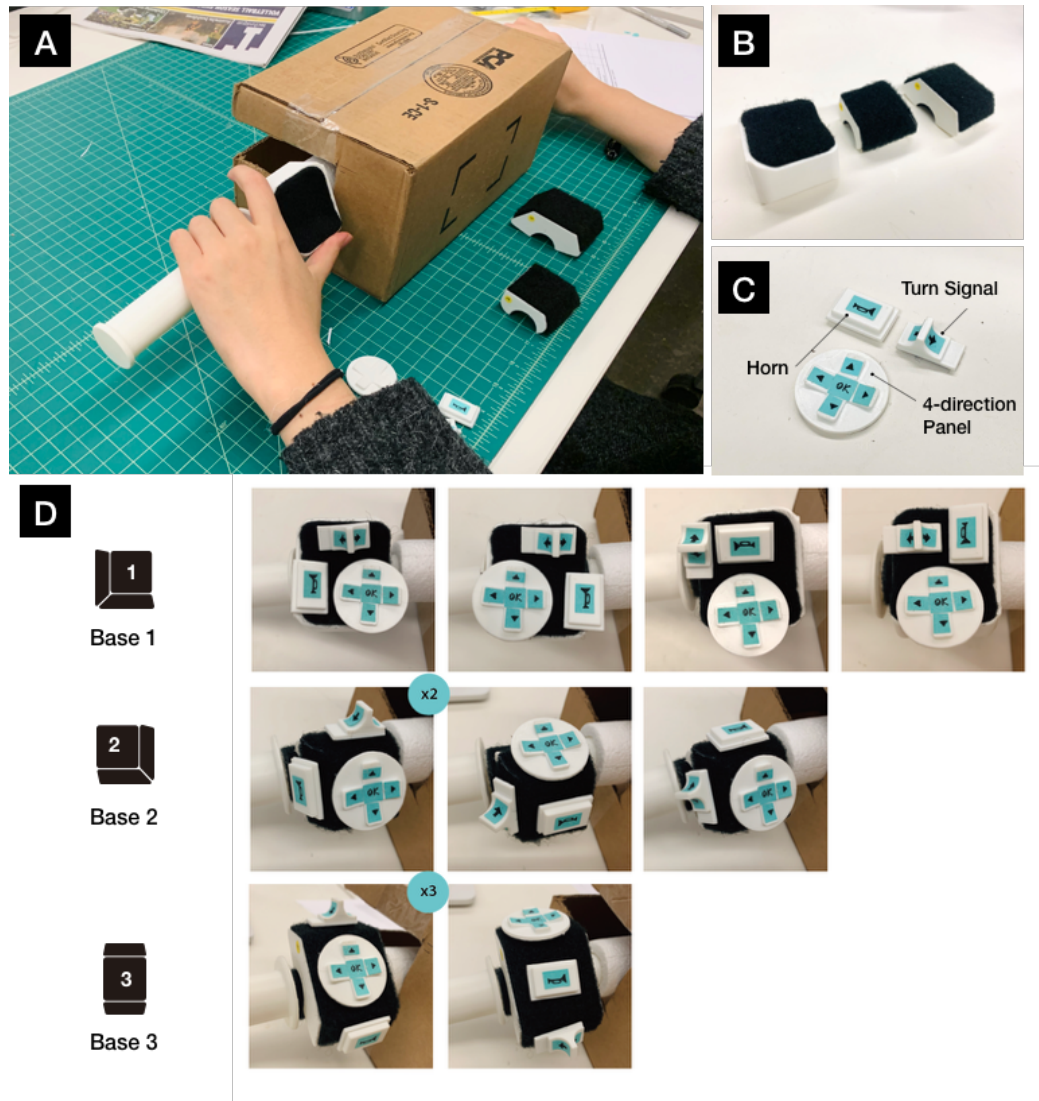


Figure 4 – 1st round prototype, A) prototype setup, B) 3 controller base, C) 3 controls, D) Synthesized layouts

Participants were asked to rate the layout they created in the following aspects: Easy and intuitive to use, ergonomic and comfortable to use, tactile, perceived safety to use. (rate form see appendix). The most common layout using the base 3 was selected to move on the next round iteration.

3.3.3.2 Smartphone dashboard functionalities

The first step is to define essential UI elements displayed on the dashboard: Constant speed, electricity consumption, control status indicators are proven to have high priority in moped dashboard design in a previous study[16] that involved 180 experienced motorcycle riders. 4 functions were selected, including basic dashboard, map and navigation, dashcam and music player and will be tested with users to evaluate the acceptance.

3.3.3.3 Smartphone integration

After comparing different types of controls, a 4-direction panel was selected to help riders navigate between screens from the handlebar. Left/right is corresponding to switching between different functions and up/down for riders to manage 3 different levels of information density. Since the displayed content and information density all contributes to drivers' mental workload and information processing[17]. Too much information and visual cues could be distractive. To avoid information overload and to accommodate different traffic conditions, the user should be provided with the flexibility of adjusting and managing information.

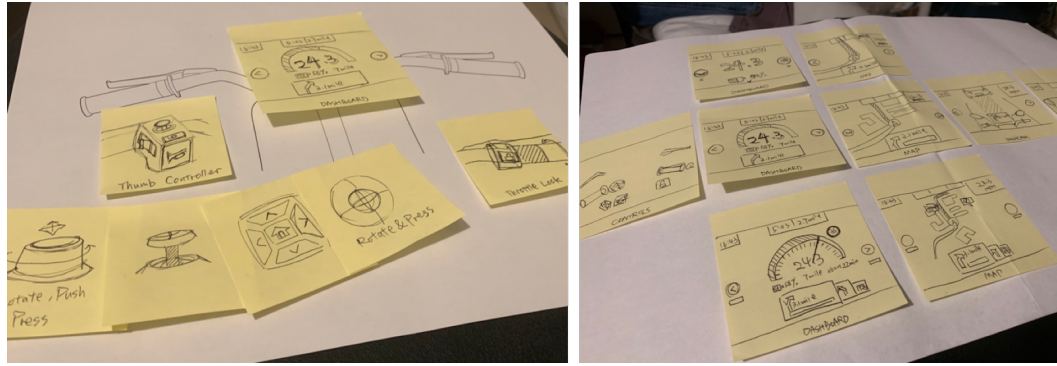


Figure 5 – Sketches smartphone integration concepts

This round of evaluation is to figure out what are the key features and to test the acceptance of the integration tactic. The initial concepts were represented using wireframe and paper prototype.

As for functionalities, dashboard and map are considered to be most useful. On the contrary, the music player feature is considered negatively because music could cover sound effects of the control and other audio cues of the traffic. Participants have positive opinions on customizing different information levels. But the differences between each screen need to be more obvious. Most people think the panel to control screens is easy to use and adding visual indicators on the screen can help the first time user to understand without further explanation.

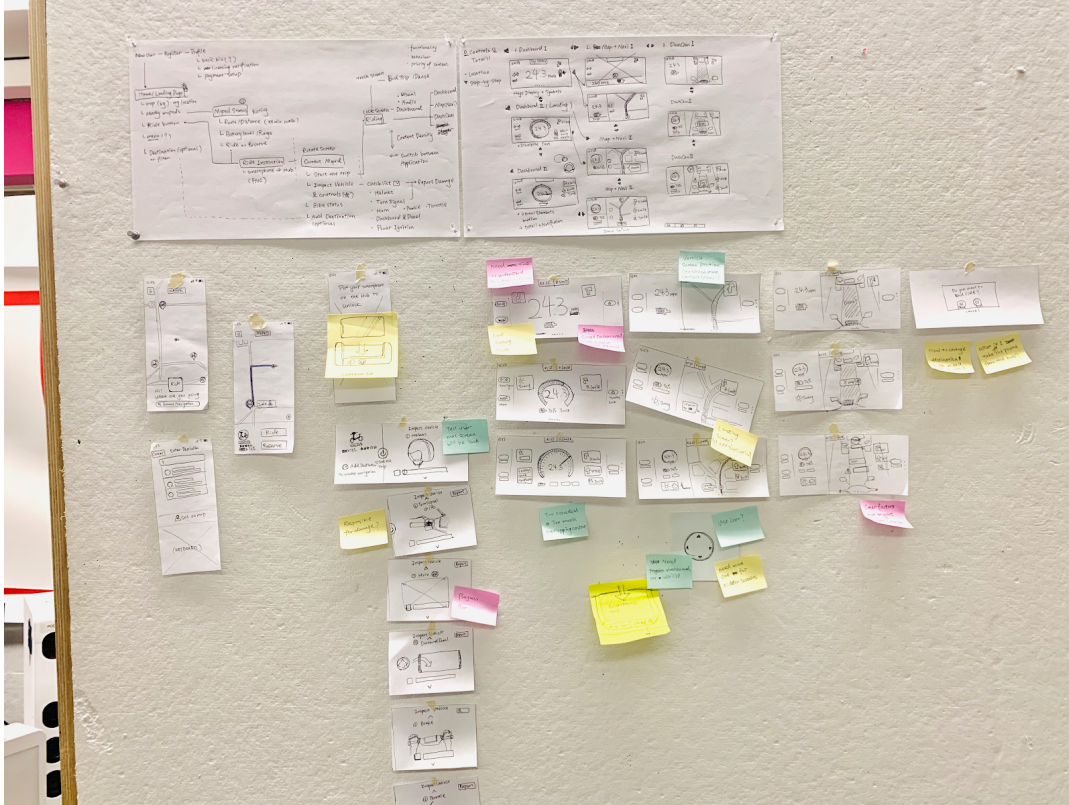


Figure 6 – wireframe of the smartphone dashboard with feedbacks(post-its)

As for functionalities, dashboard and map are considered to be most useful. On the contrary, the music player feature is considered negatively because music could cover sound effects of the control and other audio cues of the traffic. Participants have positive opinions on customizing different information levels. But the differences between each screen need to be more obvious. Most people think the panel to control screens is easy to use and adding visual indicators on the screen can help the first time user to understand without further explanation.

3.3.4 Iteration 2: low fidelity prototype

After all key features were defined and refined, a low fidelity prototype was made by assembling laser-cut cardboard pieces. Handlebar controls and smartphones are

integrated on the cardboard prototype located in the designated place. The size dimension of the physical controls and UI element are evaluated and adjusted.



Figure 7 – 2nd round prototype

3.3.5 Iteration 3: working prototype

A final prototype was built for the simulation study. To add more fidelity and mimic the real world experience, standard bike accessories including 22mm handlebar, bike brake, bike stem are directly incorporated to make sure the final prototype is true to size and ergonomically acceptable. Arduino components were used to build the controls on the handlebar with a customized cap, which is 3d printed to adjust the size and tactile of the physical interaction area. Connection between the smartphone and handlebar controls is established through a MQTT broker, which enables control of the smartphone directly from the handlebar.

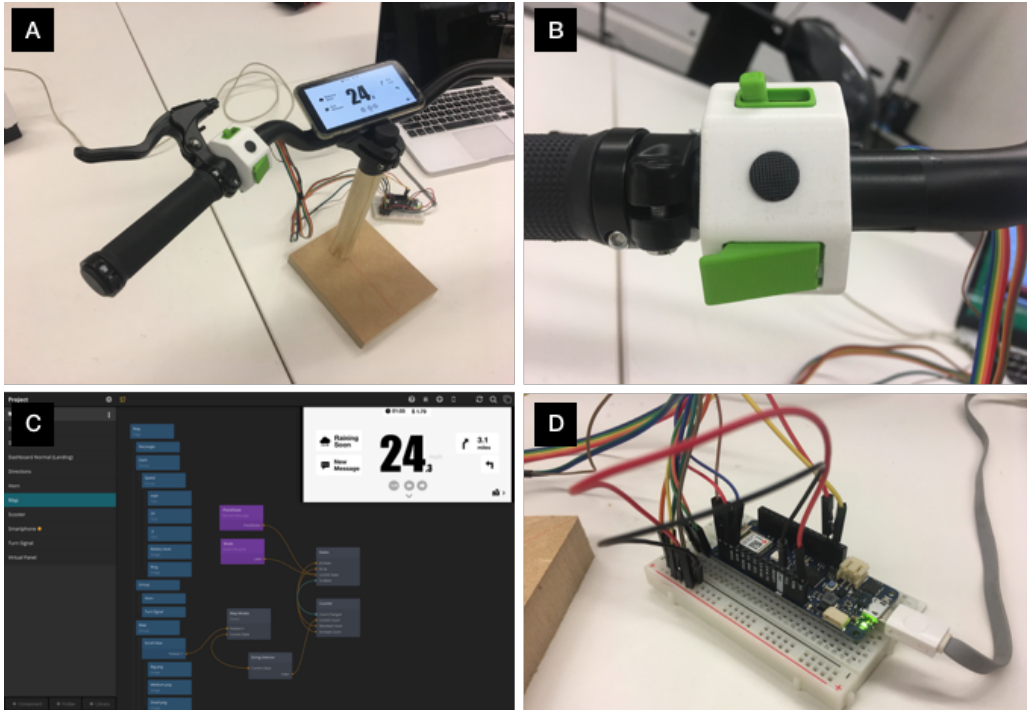


Figure 8 – Final working prototype, A) overview, B) handlebar controls, C) software programming, D) arduino processing unit

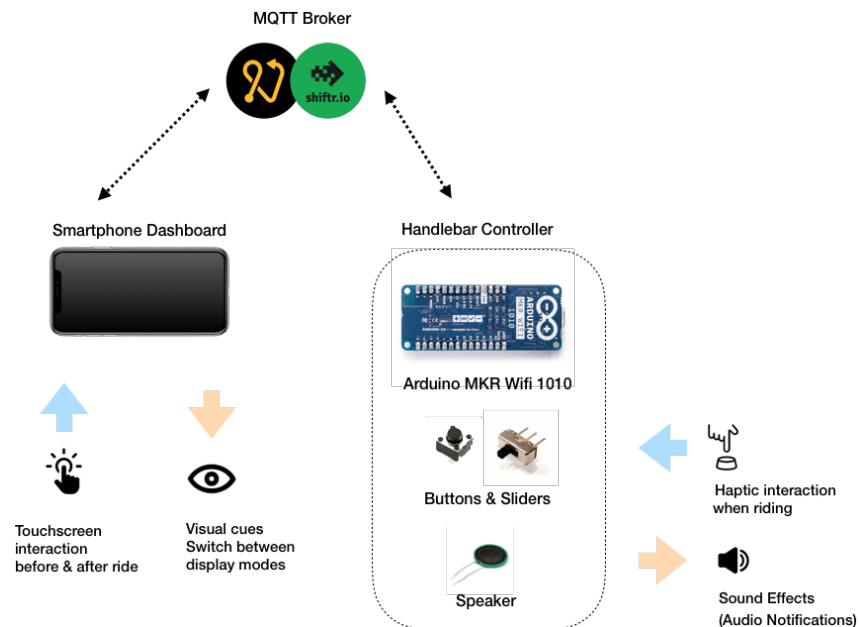


Figure 9 – System architecture for final prototype

CHAPTER 4. USABILITY STUDY

4.1 Methodology design

The moped interface designed and built in this study is to better accommodate moped sharing services and support the large portion of inexperienced users. As such, a comparative study was conducted using the final prototype against a standard moped interface. The disparity of usability was measured.

4.1.1 *Participants*

A total of 9 participants were invited (F=6, M=3), recruited via email list and word of mouth. Our inclusion criteria were: 1) participants aged over 21, 2) participants possess any kind of driver's license, car or motorcycle, which proves they have on-road experience and a good understanding of road safety. 4 of the participants have completely no experience with moped or motorcycle; 3 said they have tried a few times but not proficient; and 2 are experienced moped riders.

4.1.2 *Settings*

The final prototype, which includes handlebar controls and smartphone dashboard. The functionalities are limited to press the controls on the handlebar and change the page being displayed on the dashboard. For example, if the participants press the horn button on the handlebar, then the horn indicator (icon on the dashboard) will light up.

A standard motorcycle interface that served as a control group. A real motorcycle will be securely parked in the lab and remain static during the whole testing section. The

motorcycle will be turned on so that controls like turn signal and horn will work, but the engine and throttle will be shut down and make sure participants will not activate it by accident.

A TV Screen. The screen will be used to display recorded video of a 5min ride to make participants feel like they are riding a motorcycle and feel immersive.

The prototype and real moped will be placed side by side in a parallel position in front of the screen.

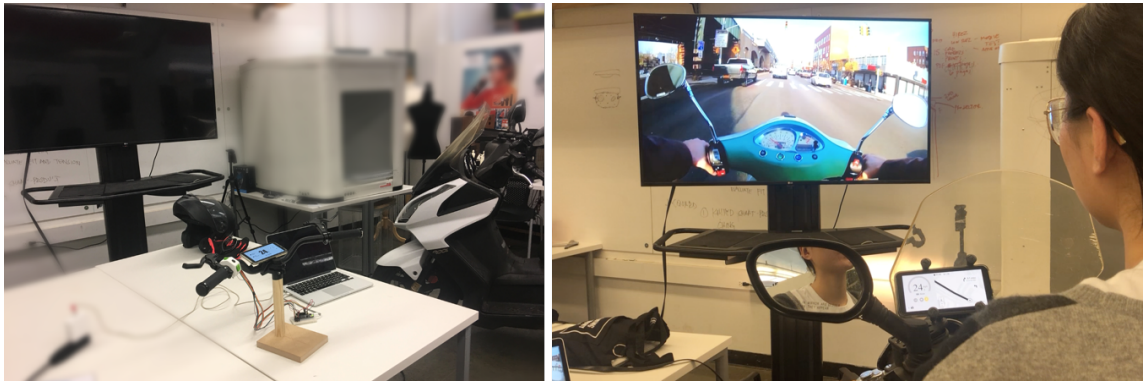


Figure 10 – Study setting

4.1.3 Procedure

Participants were invited to the lab and will do 2 simulate drives using the prototype and a regular moped respectfully. Each ride will last 5 min. Videos that show the rider's POV for the trip were pre-recorded using a camera mounted on rider's helmet. Both the prototype and standard moped will enable participants to mimic the riding in the video with steering and braking. The engine of the moped is turned off and the vehicle will be securely parked in a static position. During the trips, participants are asked to complete several tasks

to interact with handlebar controls and the smartphone while maintaining their attention on the ‘road’.

4.1.4 Data collection

After the 2 simulation rides, the participants are asked to fill out a SUS[18] review sheet and evaluate the usability for the two interfaces separately (10 scale each). Then, followed by a 20min open question interview. The participants will be guided to comment on perceived safety, easy to learn and use, intention to use the system. The interview process is recorded in audio and transcribed for further analysis. Along the process, the simulation rides are recorded in video with a focus on participants’ hand gestures and head movement as a supplementary material to study riders’ unconscious behavior.

4.2 Results

Participants’ answers of each item in the SUS rating sheet are normalized and converted to become the final SUS rating. In this comparative benchmark study, the standard moped interface received a total SUS score of 66.78, which is pretty close to the line(SUS=68) of acceptable usability and thus suggest opportunity and need for improvement. Whereas, the prototype developed and evaluated in this study achieved a higher usability score of 81.7. This overall usability rate falls in the range between good and excellent user experience referring to SUS grade ranking.

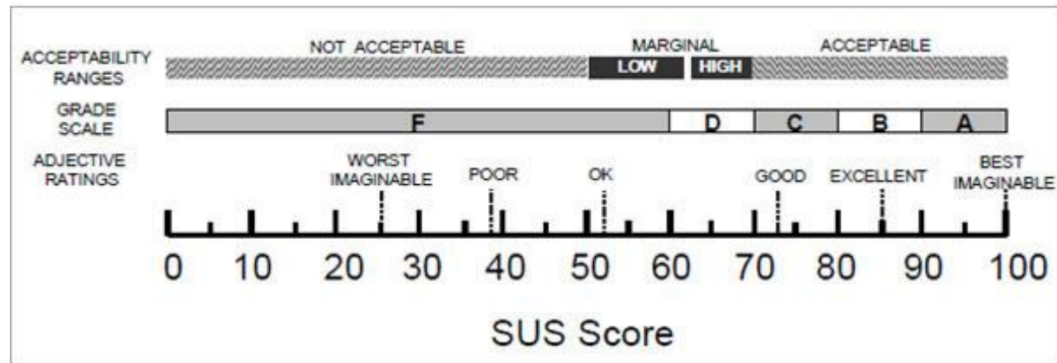


Figure 11 – Grade ranking of SUS score[19]

Apart from the analysis of overall usability, the following interview section reveals more insights about the specific user experience interacting with the prototype.

About the design of handlebar controls, participants have expressed positive opinions on the haptic guidance it provided by applying different interaction types when stating “I like that it all feels different. The slider, rocker switch and joystick”. The layout of different controls are considered to be acceptable and easy to remember after repeating the same task for a couple of times, meanwhile, some participants are suggesting and would like to try and compare different layouts. Besides, multiple users expressed positive opinion on controlling the screen display remotely from the handlebar as opposed to using touchscreen gestures, by saying they don’t need to remove their hand from then handle grip/brake so it is safer and reassuring. It is of great significance especially for novice riders to put their hands on the handle grip all the time. Some participants say that they will grip firmly when they get nervous and it could be difficult for them to maintain balance using a single hand. As there are only 5 different pages, 2 functions (dashboard and navigation) included and tested with smartphones, participants did not have difficulty navigating between different screens, and all the participants can master the operation of the remote

panel within the 5min test ride. Some suggestions are made by participants on the visual design, for instance, one participant suggests that the difference between each screen can be made more obvious.

4.3 Discussion

Electric moped sharing is a relatively new and complex practice of travel options that could become the future mobility. User experience related to this mobility mode needs to gain more attention from the design and research communities. While this paper mainly discussed how to fill the gap of inexperience and unfamiliarity, other user experience problems also need to be identified regarding the rider training, vehicle parking and charging, for instance.

Limitation for the prototype design and development: 1) when designing the layout of handlebar controls, the frequency of use is not given special consideration. The use frequency mentioned by 3 participants in the follow up interview. 2) physical controls in the working prototype are mainly using prepackaged Arduino components. Even though it saved a lot of effort in the development process, these components do come with restrictions, such as size, key stroke. Customized caps were modeled and 3d printed out to partially offset the limits, but there's still a fidelity disparity in the haptic interaction when compared against market models. 3) For inexperienced riders, doing interactions in a nervous state of mind would result in extra physical effort. As users interact with the handlebar controls using only their left thumb, the design of physical form and shape should provide more resting support as well as further reduce the moving distance for reaching different buttons.

Methodology and testing design. In evaluating a concept in the earlier stages of the development process, lab-based simulation testing is the most commonly used method and the usefulness has been widely tested. In line with previous studies, many efforts have been made to mimic a 'real world' experience in the testing design of this study. Due to the limit of facilities and development skill, the prototype used in the testing does not have the functionality of the primary riding tasks, in a word, the participants can drive by themselves. So, instead, the participants need to follow and mimic the video displayed to keep their attention 'on the road'. This tactic partially worked. When no tasks were given or the tasks only required interaction with the physical controls, it's been observed that participants' attention are naturally driven by the dynamic visual display on the tv screen. However, when instructions were given to control the smartphone dashboard, the participants suddenly forgot they were currently 'on the road' and were looking down to complete the task. Additional effort needs to be made to avoid the distraction effect and thus lead to more accurate results.

CHAPTER 5. CONCLUSISON AND FUTURE WORK

Driven by the sharing economy, modern citizens are granting access to a variety of modality options without the burden of ownership. This novel concept is not only providing convenience and flexibility for the commuters but also potentially disrupting the established transportation system and leading to a multimodal, more efficient future. While embracing this trend, we need to be aware that the public access and low entry barrier that vehicle sharing promises is starting to cause troubles as we have seen more and more reported misuse, accidents and even fatalities that occurred while using shared mobility services. In the present study, electric moped sharing is selected to be a particular case and a mixed method approach was applied to understand the user experience of novice users, especially issues caused by unfamiliarity and inexperience while interacting with the vehicle. A share friendly moped interface was proposed and evaluated in this paper, which aims to better support the inexperienced user segment. Compared against a standard commercial model, this prototype has received a higher usability score as well as suggestions for further improvement. This result indicated that novice riders' first contact with this service can be improved by low-cost design solutions, thus promoting the acceptance and adoption of electric moped sharing schemes.

Design recommendations and future work can be summarized from the data collected in this study: 1) This study shed light on a vulnerable population of traffic participants, which is the novice and inexperienced riders. This particular user segment is not raising enough awareness in the transportation communities where mainly usability problems are discussed in the context of private owned or commercial vehicles. However,

with the rise of the sharing context, the novice groups have evidently expanded. Similar to other vulnerable groups (i.e. the elderly drivers), inexperienced riders' riding performance could be heavily affected by mental conditions like nervous, fear and apprehension. Specifically, in this study, some subjects have reported stiffness, struggling to maintain balance and other undesirable situations caused by mental overload.

2) The smartphone integration tactic has received universal acceptance among the participants, which allows riders to control secondary functionalities remotely from the handlebar using a 2-axis joystick. Its impact on system perceived safety is mentioned by participants in the interview section. One main reason is this solution avoids conflict with performing primary driving tasks (i.e. rotate throttle, brake, steering) by keeping drivers' hands on the handle grip during the trip. Most first-time riders would choose to comply with the safe riding guidelines and this design highlights the significance to do so.

3) The effect of tactile information on memorizing and operation without look has been examined in the design of moped handlebar controls. In line with the effort of reducing mental workload for novice riders, the function of handlebar controls are limited to 3 basic controls. Multiple switch types (slider, rocker switch, joystick) are used to differentiate basic functions and polyhedron shapes are leveraged to secure enough spatial distance between controls. The results indicate a high level of accuracy without the need of vision and good learnability. Limitations related to ergonomics are also addressed and suggest a thorough examination size, spatial placement of controls to reduce physical effort and accommodate different hand sizes.

Currently there are 2 active moped sharing schemes inside the United States looking to expand its scale. And we have also seen some service providers leaving the market as more legislative oversight and licensing costs are introduced. Other than the problem discussed in this paper, user training, legal operation, vehicle maintenance as well as other underlying UX problems need to be addressed. With this whole area still in its infancy, designers, researchers and service providers should work together to reshape the service model for better user experience.

APPENDIX A. SURVEY QUESTIONS

Welcome!

We are interested in understanding **your opinion about the low-speed motorcycle sharing service.**

The study should take you less than 3 min to complete. Your participation in this research is voluntary.

Please be assured that your responses will be kept completely confidential. You have the right to withdraw at any point during the study, for any reason, and without any prejudice.

If you would like to contact the Principal Investigator in the study to discuss this research, please e-mail **chenxiaoyu@gatech.edu.**

By clicking the button below, you acknowledge that your participation in the study is voluntary, you are **18 years of age**, and that you are aware that you may choose to terminate your participation in the study at any time and for any reason.

- ☐ I consent, begin the study (go to Q1)
- ☐ I do not consent, I do not wish to participate (end survey)

Q1 Please tell us the frequencies of you using different transport modes.

	Everyday	Everyweek	Occasional
<input checked="" type="radio"/> Private vehicles e.g. cars, motorcycles, bikes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<input checked="" type="radio"/> Public transportation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<input checked="" type="radio"/> Shared mobility services e.g. uber, Lyft, Zipcar, Bird, Jump bikes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q2 What is your experience with riding a motorcycle/moped?

- ☐ I am an experienced rider
- ☐ I tried a few times
- ☐ No experience

Q3 This is the type of vehicle in use in the low-speed motorcycle sharing services. It is electric with a max speed of 30mph. And, most importantly, it does not require a separate motorcycle license to operate if you have a driver license.



So, will you use low-speed motorcycle sharing?

- ☐ YES (go to Q4)
- ☐ NO (go to Q5)

Q4 What are the expected use case? (multiple answer)

- ☐ Daily commute
- ☐ Shopping, go to cafe
- ☐ Walkable distance
- ☐ connect with public transportation
- ☐ Just try out for fun
- ☐ Others

Q5 What are the concerns? (multiple answer)

- ☐ I don't think I am capable of ride motorcycle without proper training
- ☐ Not needed / Not interested, I am satisfying with the current mobility options
- ☐ Had bad experience with similar services
- ☐ Motorcycles are not safe
- ☐ Undesirable weather and road conditions
- ☐ Others

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